Efficient Algorithm of B0 Drift Correction in Time Series of Phase Images

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Target audience: The method applies to all users of time-course EPI sequences run on high gradient whole body MRI scanners when the phase of images must be consistent for further processing in spite of magnetic field drift due to warm-up of ferro-shim elements.

Introduction: The purpose of this work was to transfer time-course phase correction technology developed for multiband imaging (1) to increase the quality of phase images used to improve fMRI analysis. Results obtained with a single channel RF coil helped to understand a phenomenon of unequal phase drifts in different areas of the brain that reduced the quality of multiband slice separation. This phenomenon was falsely attributed to differences in separate receive RF coils, part of 32-channel acquisition system. The problem was in a radial asymmetry of ferro-shim elements used in modern magnets to improve magnetic field uniformity. The corrected algorithm described here solved unequal phase drifts and was reapplied in the multiband separation method with success.

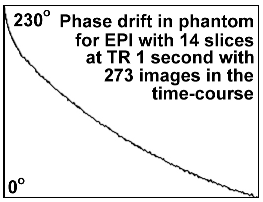

Fig.1. *B_0 drift of ~22 Hz for EPI of the phantom.*

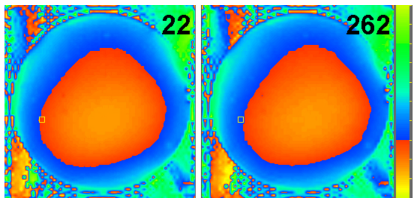

Fig.2. *Phase profiles of images 240 seconds apart and shifted by 2 pixels.*

Methods: For slice excitation we used tailored pulses formed from the inverse FT of the required slice profiles as described in (2) using a Pentek (Upper Saddle River, NJ) PCIe card model 78621. The reason was to avoid uncontrollable phase changes created by an unpublished algorithm modifying the frequency of the reference signal throughout the time-course of echo planar imaging used to correct for a Larmor frequency drift due to increasing temperature of gradient coils and adjacent ferro-shim elements. A gradient EPI sequence of our own design (3) was used. Acquisition parameters were: TR=1 sec, BW=125 kHz, FOV=19.2 cm, slice 3 mm, 1 NEX, 64×64 resolution and TE=28.2 ms. A fat suppression pulse was added for head imaging. 263 image time-courses were acquired on a GE Signa EXCITE 3T MR scanner. The maximum number of slices (14 for phantom, and 12 for head) was acquired to increase the load on gradients that increased the temperature of ferro-shim elements effectively increasing B_0.

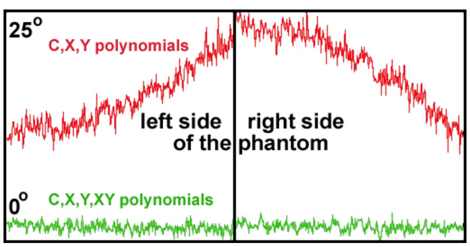

Fig.3. *Phase drifts of near the edge voxels for B_0 corrections by 3 and 4 polynomials.*

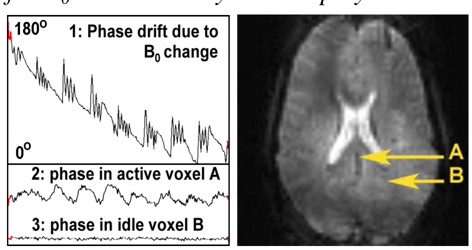

Fig.4. *B_0 drift during breath hold exercise.*

Results: Fig. 1 shows the result of a magnetic field drift due to increasing temperature inside the magnet bore. These data were obtained using a Pentek modulator. By contrast, in the factory RF configuration, the initial phase drift was slightly up, followed by continuous decrease after about 50 images not reflecting the real change of B_0. Fig. 2 shows two phase images of the same slice, 240 seconds apart, obtained after phase correction of a time-course. As described in (1) the three polynomials were used for correction: C for constant drift, X for G_x, and Y for G_y gradients noise effect. These images look the same but there is a slight shift of phase profiles, about 2 pixels to the right. Small squares set in the same position have 2x2 pixels size and make the shift obvious. This effect was unexpected and can only be explained by a non uniform distribution of ferro-shim elements that reduce susceptibilities with increased temperature. To correct the shift an additional XY polynomial was added and the result is shown in Fig.3 by green time-course lines. Without the XY polynomial, voxels on the left and right side of the phantom showed about 15-degree phase drifts, as the red graphs illustrate. These asymmetrical drifts created problems in multiband slice separation and was understood during this process. Adding 2d order polynomials with all cross terms (9 total) improved results slightly, especially for head imaging. For example, the phase graph in an idle voxel B in Fig.4 had a standard deviation of 2.4 degrees with 3 polynomials. Adding the XY polynomial reduced this deviation to 1.6 degrees, but with 9 polynomials the reduction was down to 1.2 degrees.

Discussion: The top graph in Fig.4 shows the deviation of B_0 field obtained by double-pass correction using only C polynomials. It was created by accumulated phase differences of consecutive images. The B_0 drift creates instantaneous phase changes due to the chest movement. By contrast an active voxel A shows only a slower hemodynamic BOLD response to a periodic breath hold.

Conclusion: The ferro-shim method of obtaining homogenous B_0 inside the magnet conflicts with strong gradients in such scanners. Simple cooling, without thermostat regulator, will not suffice where at high fields the phase contrast in the brain carries more information than standard, high resolution, amplitude images.

References:

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